(12) UK Patent Application (19) GB (11) 2 353 166 (13) A

(43) Date of A Publication 14.02.2001

(21) Application No 0014691.0

(22) Date of Filing 15.06.2000

(30) Priority Data
(31) 19927129 (32) 15.06.1999 (33) DE

(51) INT CL[7]
A61B 1/05, G02B 7/09

(52) UK CL (Edition S)
H4F FCK FJS
G2J JE J23C

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition R) H4F FAAA FCK FJS
INT CL[7] A61B, H04N
ONLINE: EPODOC, JAPIO, WPI

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(54) Abstract Title
A focussing and focal length adjusting device for a video camera

(57) The device includes a focussing lens (15) of a lens system mounted in a sleeve (16) which is connected by film or wire link members (13, 14) to free ends of two or three spaced piezoelectric bending actuators (10, 11), the opposite ends of which are fixed relative to an associated camera head. A focussing circuit supplies a focus adjusting signal to the actuators (10, 11) causing their free ends to move transversely (AB) to an optical axis of the lens (15) which causes the lens (15) and sleeve (16) to move along the optical axis. A zoom objective (figure 5, not shown) of the lens system is mounted in a zoom sleeve (42) with a radially projecting pin (32) which engages a helical groove (41) in a roller (31) mounted on a shaft of a stepper motor (30) which is supplied with a zoom adjusting signal from a zoom control circuit (36). The focus and zoom adjusting signals are only generated within a video image vertical blanking interval time window to avoid focus and zoom induced picture distortion.

Fig. 2

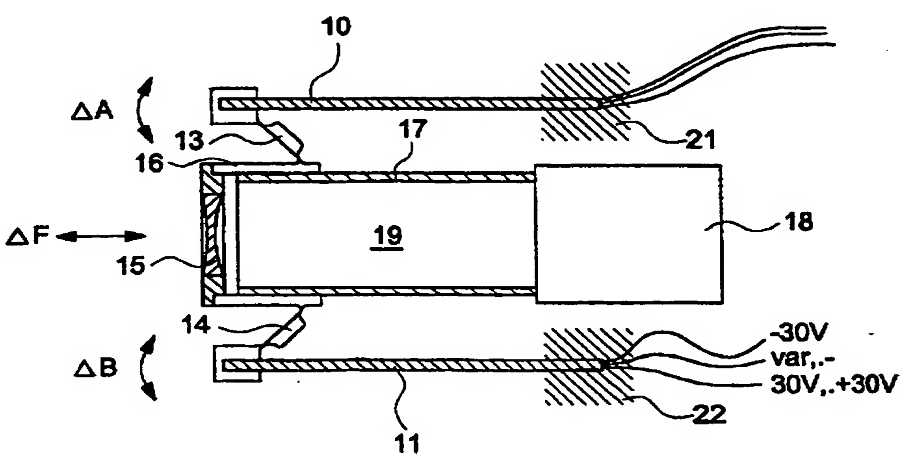

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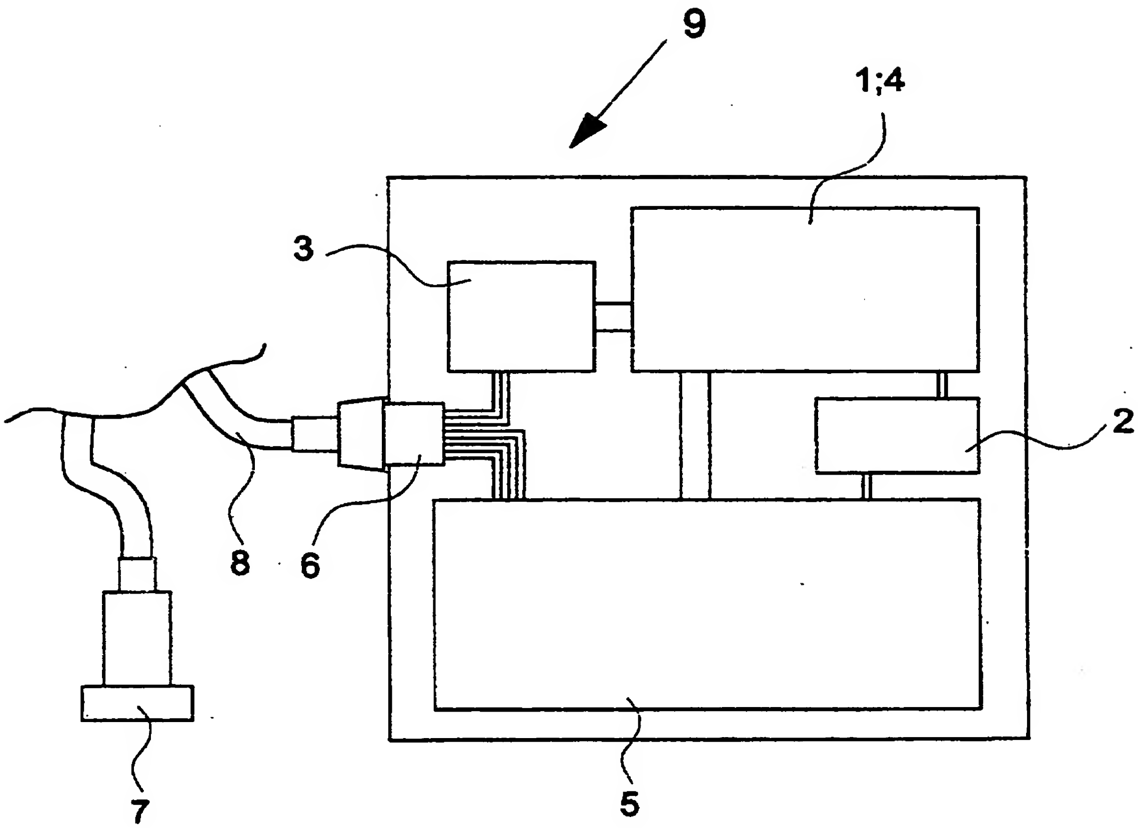
Fig. 1



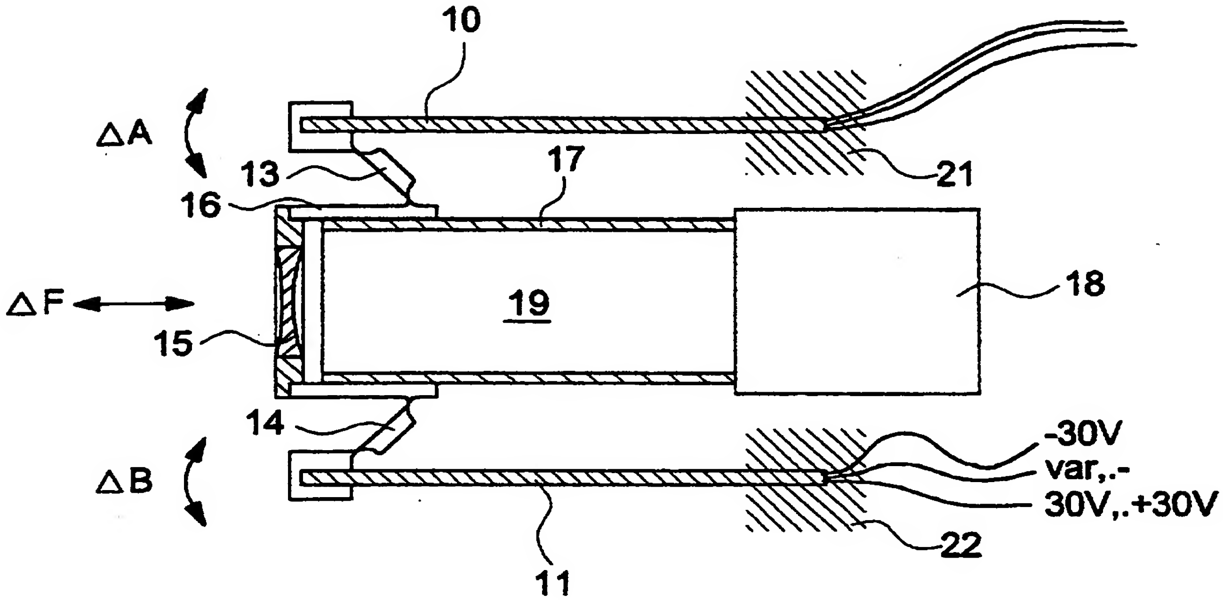


Fig. 2

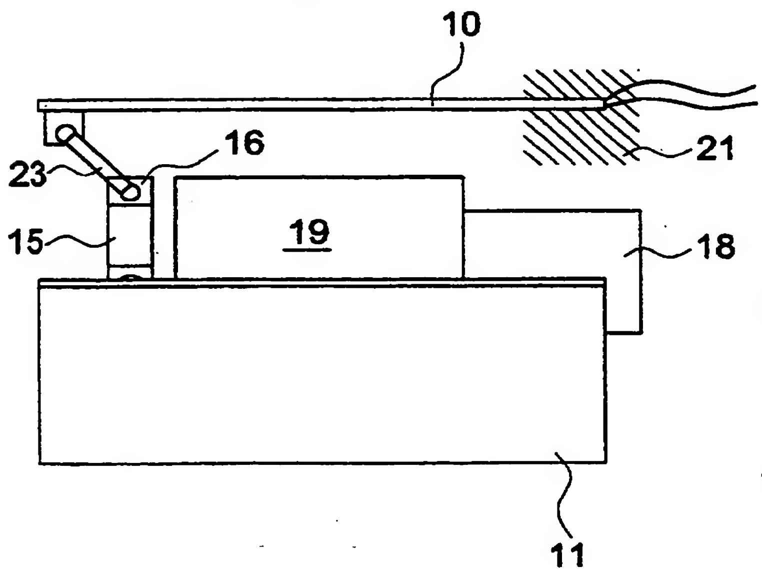


Fig. 3

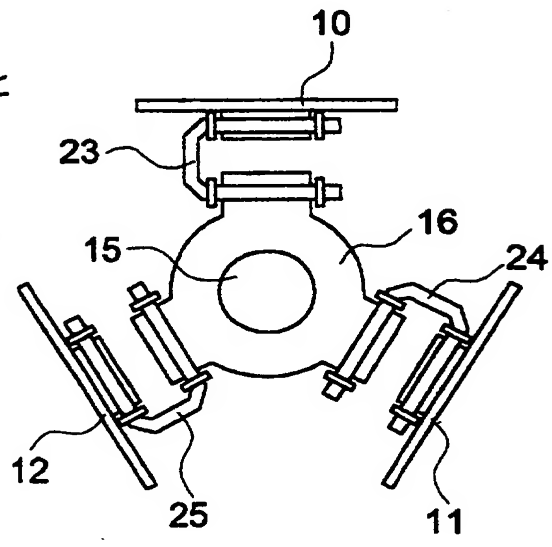
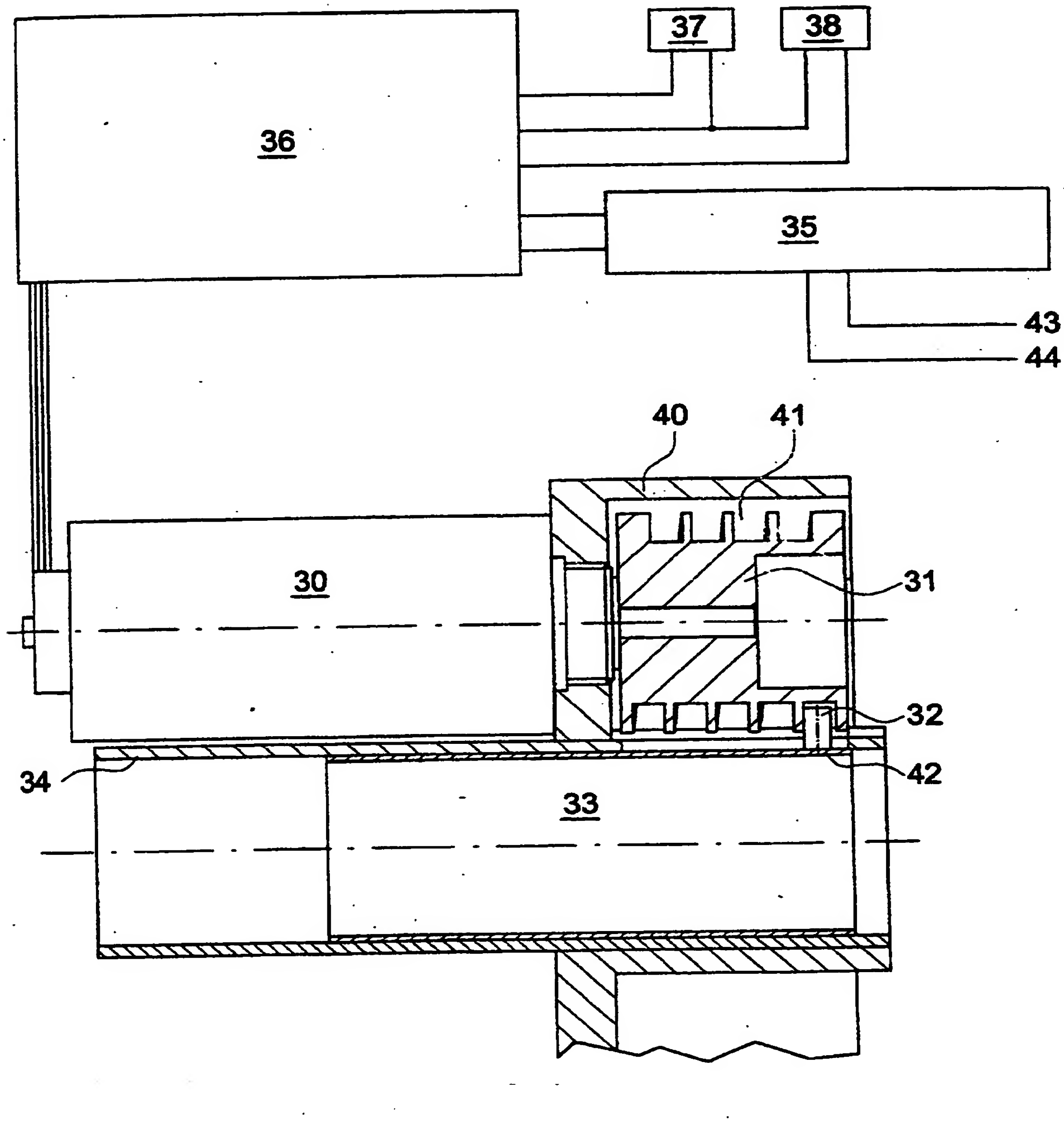


Fig. 4

Fig. 5



A FOCUSSING AND FOCAL LENGTH ADJUSTING DEVICE FOR A VIDEO CAMERA

The invention relates to a focussing and focal length adjusting device for a video camera, in particular for an optical lens system in an endoscopic video camera, with a drive device moved by at least one piezoelectric actuator, for a focussing lens of the lens system. The device includes an automatic focussing circuit for producing a focus adjusting signal which can be supplied to the piezoelectric actuator, and an electromotor zoom drive, connected to a zoom objective of the optical lens system. A zoom control circuit with a manually inputted zoom signal produces a focal length adjusting signal for the zoom drive.

Particularly with endoscopic applications in which the operating surgeon does away with an assistant guiding the camera and holds the camera himself or has it fixed by way of a mechanical holding arm, the automation of frequent picture focussing readjustment means a significant handling improvement which permits the operating surgeon to concentrate more on the surgical or diagnostic activity. In endoscopy an autofocussing operation may only be acceptable when it is not noticeable to the human eye. Accordingly the control system used as well as the drive must be very quick-acting. Furthermore, neither the drive in the camera head nor that in the cable to the camera controller may cause disturbances of the picture signal.

Autofocussing devices in conventional video cameras frequently use electric motors which drive a linearly

guided focussing member *via* a spindle. A further movement using electric motors is effected by toothing on the circumference of a sleeve containing the focussing member, in order to rotate the sleeve. This rotational movement by way of a helical slot in the sleeve is converted into a translatory adjustment of the focussing sleeve. The use of electric motors in endoscopic camera heads often causes disturbances in the video picture which may not be acceptable. Furthermore, electric motors may only be moved successively in one direction, and a jump-like movement to a certain target position is not possible with them. Thus with electric motors the demands for a rapid focus adjustment which is unnoticeable to the eye can only be fulfilled with difficulty.

From the US patent 5,490,015 there is known an automatic focussing device for a video endoscope which comprises a piezoelectric actuator for moving a focussing lens. This known focussing drive is based on the properties of a piezoelectric stack actuator, with several platelet-shaped piezoelectric ceramic elements and interleaved electrode layers stacked over one another and which extends in a jump-like manner with a suitable activation. The piezoelectric actuator positioned in a groove by a clamping device overcomes sticking friction by way of a mechanical impulse which results from its jump-like extension. In this manner the actuator may slide into the groove and the focussing lens holder connected to the actuator may be moved over a short period of time. Successive repetition of this short movement leads to a perceivable adjustment. The direction of adjustment is determined by the shape of the flanks of an activation voltage which is applied to the piezoelectric actuator.

In order however to achieve an adequate adjustment the piezoelectric actuator receives a sequence of voltage impulses within a certain period of time. These voltage impulses may, in the video picture, lead to visible disturbances since a certain cross talking onto the video signal leads in the cameral cable cannot be avoided. The same applies to the close proximity of the control actuators to the sensitive camera head.

In the field of vario-objective control, i.e. for the activation of a zoom objective of a camera there are known a series of drive systems. From DE 43 12 489 A1 and EP 0 634 680 A2 there are known motor drive units for vario-objectives which use a synchronous motor or brush motor and for transmission use pinions, gearwheels and helical guides. For the application in standard video cameras this is a practical solution. In the field of endoscopic video cameras however, the operation of such electric motors causes disturbances in the video picture. Furthermore, these electric motors are not suitable as drive units in video endoscopes on account of their considerable space requirement.

It is the object of the invention to provide a focussing and focal distance adjusting device for an optical lens system of a video camera, in particular for an endoscope, in which disturbances of the picture signal are caused neither in the camera head nor in the cable to the camera controller. Furthermore, a drive for the focussing device is to be made which is as small and as light as possible, which will minimise the forces exerted by the endoscope on body openings and which will only require a short focussing path. Accordingly the device

satisfies great demands, on the resolution of the adjusting path of the focussing drive or of the transmission. Furthermore the drive provided for adjusting the zoom objective should be precise and not cause any noticeable shaking or picture distortions as the zoom operation occurs.

One focussing and focal length adjusting device achieving this object is specified in claim 1. An essential aspect of this device lies in the production, i.e. the detection and use of a time window on the basis of the extracted vertical synchronisation impulse in the video signal. The time window is led to the focussing circuit and the zoom control circuit, wherein the focussing circuit transmits the produced focus adjusting signal to the piezoelectric actuator, and the zoom control circuit transmits the focal length adjusting signal to the zoom drive, only within the vertical blanking interval indicated by the time window.

Since only time periods of e.g. 1.6 ms, not influenced by the reading-out of the video picture data in a cycle of 20 ms in the television system according to CCIR or PAL-standard, are used for producing the focus adjusting signal for the focussing device and for producing the focal length adjusting signal for the zoom operation, picture disturbances caused by the interference of the video signal by activation currents may be eliminated.

The focussing device according to the invention uses piezoelectric bending actuators for the movement of the focussing member. Two or three strip-like bending

actuators are positioned laterally parallel to the optical axis along the objective and for example are fixed by moulding into a stationary part. If an electrical charge is supplied to the piezoelectric bending actuators their non-fixed ends deflect. Via link members the produced movement is transmitted to a focussing sleeve enclosing the focussing lens. The direction of the movement, which with the bending actuator runs originally orthogonally to the optical axis of the system, by way of the inclination of the link members, is converted into a movement along the optical axis. The jump-like positioning prevents disturbing blurring phases, e.g. during starting procedures or great contrast changes. Furthermore, the speed of the piezoelectric actuator permits the use of the short time window between two video half-pictures for adjusting the focus.

With the stepper motor used according to the invention for the focal length adjusting device of the zoom lens system one adjusting step may be initiated in each blanking interval. Via a grooved roller connected to the shaft of the stepper motor and the pin connected to the zoom sleeve the rotor's rotational movement is converted into a linear axial movement of the zoom sleeve. This type of guiding compared to the known methods (pinion guiding, crown gear guide, helical guide) provides particularly low play and friction. The thread length of the grooved roller corresponds exactly to the zoom path. By way of the pitch of the groove thread the desired zoom speed may be set. In the half step mode the stepper motor runs particularly smoothly, which is why this half-step mode is to be preferred.

The invention is hereinafter described in more detail by way of examples shown in the drawings. In the drawings:

FIG. 1 shows schematically as a function block diagram, a focussing circuit activating a focussing device according to the invention;

FIG. 2 shows schematically a longitudinal section through a first embodiment of a focussing device according to the invention;

FIG. 3 shows schematically a longitudinal section through a second embodiment of a focussing device according to the invention;

FIG. 4 shows a schematic cross-section through the second embodiment, shown in Fig. 3, of a focussing device according to the invention; and

FIG. 5 shows schematically and in longitudinal section an embodiment of a focal length adjusting device according to the invention in combination with a zoom control circuit represented as a function block diagram.

A focussing circuit is shown in Fig. 1 schematically as a function block diagram in a controller block 9 of an endoscopic camera, a unit 1 for evaluating the picture focus and outputting an in-focus value, a V-sync stripper 2, an electronic potentiometer 3, a unit 4 for activation of the potentiometer with a multi-bit signal, a video camera controller 5 and an interface 6 are connected to a connection cable 8 which leads to a camera head 7 in which the focussing drive device described further below and the electromotor zoom drive are incorporated.

The connection cable 8 between the camera head 7 and

the controller block 9 may be a few metres long. This cable 8 is separated into control leads for the drive for the focussing lens in the camera head 7, leads for the camera functions and leads for the picture data. With this arrangement the alternating amplitudes of the activation currents of the drives for the focussing lens would usually cause disturbances in the video signal. A disturbance-free activation of the drives in the camera head 7 may only be ensured when these drives are not activated or function at the same time as the picture data transmission. According to the invention the pause between the video half-pictures for this separation with respect to time is used. It is initiated by a clearly differentiatable rectangular impulse - the vertical synchronisation impulse (V_{sync}) in the video signal. This rectangular impulse is used in order to determine the phase in which no picture data transfer occurs and the piezoelectric actuators of the focussing drive device as well as the stepper motor of the zoom drive may be supplied with voltage for changing their position.

With a passive method the picture focus, or a value for the degree of an in-focus position is evaluated in the unit 1. This value is processed further in the unit 4 which for example is designed as a micro-controller. The transferred value is compared to earlier values and from this comparison a new input value for the electronic potentiometer 3 is evaluated. This input value is transmitted to the electronic potentiometer 3 in a 17 bit format, wherein the activation of the potentiometer 3 with the new value is effected only after the transfer of the 17 bits. The last bit is only transmitted when by way of the front flank of the vertical synchronisation impulse

V_{sync}, which is either obtainable as a direct signal from the camera electronics or is extracted by the V-Sync stripper 2 from the video signal, an authorisation is reached. In this manner the resistance of the potentiometer is only changed at the beginning of the blanking signal. A voltage jump is triggered by way of this, at the middle position of the later described piezoelectric bending actuators, permits a current flow from or to the piezoelectric bending actuators until the voltage defined by the potentiometer 3 is fully applied to the piezoelectric bending actuators. This process is also effected in less than 1.6 ms at the maximum deflection position of the piezoelectric actuators from their zero position. Thus the complete adjustment of the drive device effecting the focussing may take place within the vertical blanking interval, and thus no disturbances occur in the video picture.

In Fig. 2, which schematically shows a longitudinal section through a first embodiment using piezoelectric bending actuators, two parallel strip-like elongate piezoelectric bending actuators 10 and 11 are positioned symmetrically to the optical axis of an optical lens system 19 contained in a sleeve 17 and at one end are fixed for example by moulding in fixing locations 21 and 22. As mentioned above, when there is supplied to these actuators an electrical charge in the vertical blanking interval, the non-fixed ends of the piezoelectric bending actuators 10 and 11, shown on the left in Fig. 2, deflect (arrows A and B) in this time interval. This deflection is transmitted *via* in each case one link member 13 and 14 to an outer sleeve 16 carrying a focussing lens 15. The direction of the movement, which is originally orthogonal

to the optical axis of the system is by means of the inclination of the connection element contained in the joint members 13 and 14 converted into a movement ΔF along the optical axis.

In the embodiment shown in Fig. 2 the tilting of the focussing lens 15 is prevented by the linear guiding properties of two slidingly movable sleeves displaceable within one another, i.e. the inner sleeve 17 containing the lens system 19 and the outer sleeve 16 containing the focussing lens 15.

The piezoelectric bending actuators 10 and 11 in Fig. 2, which are designed as bimorphous piezoelectric bending actuators, receive from the focussing circuit described above with reference to Fig. 1, a variable voltage between -30 V and +30 V corresponding to the desired deflection and which is applied to their middle position whilst the outer electrodes are supplied with a static voltage of in each case -30 V and +30 V. The piezoelectric bending actuators 10 and 11 are activated synchronously.

In Figs. 3 and 4 which respectively show schematically a longitudinal section and a cross section through a second embodiment of a focussing device according to the invention equipped with piezoelectric bending actuators, three piezoelectric bending actuators 10, 11 and 12 are arranged parallel to and symmetrically around the optical axis of the focussing lens 15 angularly displaced by 120° from each other.

The redirection of the bending movement of the free ends of the piezoelectric bending actuators 10, 11 and 12

is effected with this embodiment by the wire joints 23, 24 and 25 which are attached to the circumference of the focussing lens holder 16 at locations spaced from each other by 120°. By way of this type of suspension a linear guiding of the focussing lens as shown in Fig. 2 may be done away with. Deflection differences of the three actuators, 10, 11 and 12 may be compensated by activation.

The sleeve 17 containing the camera lens system 19 connects a recorder system with a CCD sensor or with a prism and three CCD sensors as usual and this focussing device is arranged in the camera head (Fig. 1).

The enormous speed with which the deflection of the piezoelectric bending actuators 10, 11 and 12 with the embodiments shown in Figs. 2 to 4 may be realised opens up varying possibilities of providing passive control, as is practised in video technology, with more effective algorithms. The jump-like positioning prevents the disturbing unfocussed phases which otherwise occur during starting procedures with usual electromotor autofocussing devices. As a consequence of the speed of the actuators as mentioned, the time window given by the vertical blanking interval, between two video half pictures may be used for focussing adjustment. In this manner, with the focussing device according to the invention, picture disturbances arising as a consequence of interference, the video signal with the activation currents of the drive may be eliminated.

Fig. 5 shows schematically and in longitudinal section an embodiment of a focal length adjusting device according to the invention in combination with a zoom

control circuit shown as a function block diagram. A stepper motor 30 which is fixed in a motor mounting 40 drives a grooved roller 31 with a helical groove thread 41. Via the grooved roller 31 the movement of the shaft of the stepper motor 30 is transmitted to a pin 32 which is connected to a zoom sleeve 42 guided in an outer sleeve 34. The pin 32 transmits the axial force to the zoom sleeve 33 and displaces it in the axial direction. This type of guiding in comparison to the known solutions is particularly low in play and friction. The motor mounting 40 also provides centering and fixing of the outer sleeve 34.

The thread path of the grooved roller 31 seen axially corresponds exactly to the zoom path. Via the pitch of the groove thread 41 the desired zoom speed may be set. A further possibility of adjusting may be effected *via* the operating mode of the stepper motor 30. In the half-step mode the angle increment is 9° which with a supply with a 50 Hz alternating voltage corresponds to a rotational speed of 1.25 s^{-1}. However the half step mode distinguishes itself by a higher running smoothness of the stepper motor 30 which is why this mode is to be preferred.

The grooved roller 31 consists preferably of plastic, aluminium, titanium or another light metal. However other materials of a higher density may be used as long as the torque of the stepper motor 30 is high enough to overcome the moment of inertia of the grooved roller 31.

The upper section of Fig. 5 comprises a block diagram showing a zoom control circuit which includes a control

block 36 connected to zoom buttons 37 and 38 and a programmable gate array 35 which obtains a video signal 43 and in particular, with colour dividing prism systems, delivers a signal 44 for "colour shading". The control block 36 contains a motor driver and where appropriate a mains part.

The operation of the stepper motor 30 is effected in such a manner that in both of its phases, during the period of the actuation of the key 37, it is permanently supplied with current and also during the CCD blanking. However the pole reversal of the phase current, and thus the release of a step increment occurs, in each case synchronously with the beginning of the "blanking interval". During the duration of the "blanking interval" the rotor of the stepper motor 30 moves into its respective new position. This is effected in approximately 500μs so that at the beginning of the CCD blanking, after the "blanking interval", a change of the phase current no longer takes place and thus no disturbance of the video picture is caused. Flow of current to the motor phases during the blanking-free phases only is not useful since the rotor of the motor 30 in this case tends to oscillate and accordingly would possibly execute undefined step increments.

The half-picture blanking frequency and thus also the repeating frequency of the blanking-free time window is 50 Hz, i.e. in the cycle of 20 ms as mentioned above is available for a time window of 1.6 ms for the respective step element. With an angular increment of the motor 30 in the half step mode of 9° there results an angular speed of $50s^{-1} \times 9° = 450°/s$ and thus a rotational speed of

1.25 s^{-1}. Thus, *via* the pitch of the thread of the grooved roller 31, the adjusting speed of the zoom drive may be set. As mentioned it is also possible to operate the motor at double frequency, i.e. to initiate two step increments per "blanking interval". In this manner a doubling of the adjusting speed can be achieved.

Apart from the control of the motor driver in the block 36 by way of the video signal 43 and of the freely-programmable gate array 35, a signal 44 proportional to the respective zoom position may be produced for "colour shading".

CLAIMS:

1. A focussing and focal length adjusting device for a video camera, in particular for an optical lens system in an endoscopic video camera, with a drive device moved by at least one piezoelectric actuator, for a focussing lens of the lens system, with an automatic focussing circuit for producing a focus adjusting signal which can be supplied to the piezoelectric actuator and with an electromotor zoom drive, connected to a zoom objective of the optical lens system, with a zoom control circuit which with a manually inputted zoom signal produces a focal length adjusting signal for the zoom drive, wherein from a vertical synchronous impulse obtained as a direct signal from the camera electronics or extracted from the video signal by way of an extraction circuit, there is produced a time window which is supplied to the focussing circuit and the zoom control circuit, and the focussing circuit leads the produced focus adjusting signal to the piezoelectric actuator of the drive device and the focal length adjusting signal is led to the zoom control circuit of the zoom drive only within a vertical blanking interval given by way of the time window.

2. A device according to claim 1 wherein the focussing circuit comprises a picture focussing acquisition device which acquires the degree of an in-focus position of the focussing lens, and a comparative device which compares the acquired degree of focussing with the earlier degree of focussing and from the comparison produces an input signal for a voltage generator by means of which a focussing voltage corresponding to a focussing lens position is led to the

piezoelectric actuator during the vertical blanking interval.

3. A device according to claim 2 wherein the voltage generator is an electronic potentiometer.

4. A device according to claim 3 wherein the focussing circuit comprises a microprocessor which produces the input signal for the electronic potentiometer as a multi-bit signal.

5. A device according to any one of claims 1 to 4 wherein a focussing device comprises two parallel strip-like piezoelectric bending actuators lying opposite one another on two sides of a focussing sleeve encompassing the focussing lens and symmetrically with respect to and along an optical axis of the focussing lens, free ends of said actuators being connected *via* in each case one joint member to the focussing sleeve, and a focussing voltage produced by a voltage generator or the electronic potentiometer is synchronously supplied to both bending actuators.

6. A device according to claim 5 wherein a sleeve containing optical components of the lens system is slidingly arranged for the linearly guided movement within the focussing sleeve.

7. A device according to claim 5 or 6 wherein the joint members are plastic film joints.

8. A device according to any one of claims 1 to 4 wherein a focussing device comprises three strip-like

piezoelectric bending actuators mutually angularly displaced by 120° and lying symmetrically with respect to and along an optical axis of the focussing lens and at the sides of a focussing sleeve encompassing the focussing lens, free ends of said actuators being connected to the focussing sleeve *via* in each case one joint member and a focussing voltage produced by a voltage generator or electronic potentiometer is synchronously supplied to the bending actuators.

9. A device according to claim 8 wherein the joint members are wire joints.

10. A device according to any one of claims 5 to 9 wherein ends of the bending actuators, lying opposite the free ends, are fastened to a head of the camera.

11. A device according to any one of claims 1 to 10 wherein the zoom drive comprises a stepper motor which can be activated by the zoom control circuit such that it is adjustable in each case by one step or half a step per vertical blanking interval.

12. A device according to claim 11 wherein the zoom objective is encompassed by a zoom sleeve linearly guided in an outer sleeve fixed in a head of the camera and the zoom sleeve comprises a radially projecting pin engaging through an axial longitudinal slot of the outer sleeve, said pin engaging with low play and low friction a helical groove of a grooved roller sitting in an axial extension of a shaft of the stepper motor in a manner such that the rotational movement of the motor shaft is converted into an axial movement of the zoom sleeve, and wherein the

length or axial extent of the helical groove of the grooved roller corresponds to that of a zoom adjusting path.

13. A device according to claim 11 or 12 wherein the zoom control circuit activates the stepper motor in the half-step mode.

14. A device according to claim 13 wherein a half step of the stepper motor corresponds to an angle increment of 9°.

15. A device according to any one of claims 12 to 14 wherein the grooved roller consists of plastic or light metal.

16. A focussing device for a focussing lens of a camera lens system in particular in a camera head of an endoscope, wherein a drive device, for receiving a focus adjusting signal produced on the basis of an acquired focus signal by a focussing circuit, comprises at least one piezoelectric actuator, the displacement of which is transferred to the focussing lens by a connection member, wherein at least two strip-like piezoelectric bending actuators lie at the sides of a focussing sleeve encompassing the focussing lens, symmetrically with respect to and along an optical axis of the focussing lens, a free end of each actuator being connected to the focussing sleeve *via* one joint member in each case such that their bending deflection is converted into a linear displacement of the focussing sleeve in the direction of the optical axis.

17. A device according to claim 16 wherein a sleeve containing optical components of the camera lens system is slidingly movably arranged within the focussing sleeve for the linear guiding focussing movement.

18. A device according to claim 16 or 17 wherein the joint members are plastic film joints.

19. A device according to claim 16 wherein there are provided three strip-like piezoelectric bending actuators mutually angularly displaced by 120° and lying symmetrically with respect to and along the optical axis of the focussing lens at the sides of a focussing sleeve encompassing the focussing lens.

20. A device according to claim 19 wherein the joint members are wire joints.

21. A focussing device according to claim 19 or 20 wherein ends of the bending actuators lying opposite the free ends are cast into an outer stationary part.

22. A focal length adjusting device for a camera lens system of a video camera, containing a zoom objective, in particular for an endoscope, with an electromotor zoom drive connected to the zoom objective and with a zoom control circuit which with a manually inputted zoom signal produces a focal length adjusting signal for the zoom drive, wherein the zoom drive comprises a stepper motor and the zoom objective is encompassed by a zoom sleeve which is guided for linear movement in an outer sleeve and which comprises a radially projecting pin projecting through an axial longitudinal

slot of the outer sleeve, said pin engaging with low play and low friction in a helical groove of a grooved roller sitting in an axial extension of a shaft of the stepper motor, in a manner such that the rotational movement of the motor shaft is converted into an axial movement of the zoom sleeve.

23. A device according to claim 22 wherein the stepper motor is activated by the zoom control circuit in the half step mode.

24. A focal length adjusting device according to claim 23 wherein a half step of the stepper motor corresponds to an angle increment of 9°.

25. A focal length adjusting device according to any one of claims 22 to 24 wherein the grooved roller consists of plastic or light metal.

26. A focussing and focal length adjusting device substantially as herein described with reference to the accompanying figures.

27. A focussing device substantially as herein described with reference to the accompanying figures.

28. A focal length adjusting device substantially as herein described with reference to the accompanying figures.